Faculty Working Papers

ECONOMIC AND PSYCHOLOGICAL APPROACHES TO RISK-BEARING: THEORY AND EXPERIMENTAL EVIDENCE*

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Summary:

This paper contrasts the types of motivating questions, theories and models, and theoretical explanations of phenomena in the economic and psychological literatures on risk-bearing. An experimental methodology for the verification of the economic theory of risk-bearing is developed, and results of a pilot set of experiments using this methodology are presented. Tentative support for the risk consistency hypothesis of economic theory is found.

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1. Introduction

It is instructive to constrast the approaches to the study of risk-bearing decisions exhibited in the psychological and economic literatures. This topic is of widespread interest and application in both disciplines, and displays vividly the depth and breadth of stylistic differences between the disciplines. In this section, we will outline the types of questions which appear to motivate the study of risk choices in the two literatures.

The next section will contrast the economic theory of risk-bearing with two alternatives proposed by Coombs [1975] and Kahnemann and Tversky [1979]. The third section will mention the explanations these theories provide for observed gambling and insurance behavior. The fourth section will contrast the methodology exhibited in the psychological literature with the methodology we propose, which is capable of economic interpretation as verification (or rejection) of theory. We do not find this to be true of the usual experimental methodology reported by psychologists.

As sections 1-4 indicate, research by psychologists in this area has largely been comprised of attempts to refute and/or reconstruct conclusions and paradigms in the economic literature. Only recently have economists based their research on developments in psychology.[1]

To some extent, this trend continues in the following portion of this paper, which reports on experiments we conducted as a prototype of economic experimentation on risk-bearing. These experiments neither support or contradict the experimental evidence proffered by psychologists. Rather we attempted to carry out the methodology outlined in section 4, in order to bring economically interpretable experimental evidence to bear upon the question of the validity and generalizability of the economic theory of risk-bearing.

The experimental procedures and design are reported at the end of section 4, hypotheses and results are reported in section 5 and discussed in section 6. Section 7 concludes, summarizes, and suggests extensions.

We are naturally more familiar with the economic approach[2] to these problems than with psychological approaches. A serious attempt has been made to discover the major beliefs and developments in the psychological literature, and to present this approach fairly and constructively and the motivations which the writings suggest underly it. We would appreciate reference to any major papers overlooked and information on other shortcomings of our characterization.

The shorter clauses "economists theorize," "psychologists believe" and the like will be used frequently below. We emphasize, however, that we do not know what it is that all economists or all psychologists believe, trust, or suspect. These references result from explicit statements in the cited literature, or from inferences drawn from the literature: if the psychological literature contains many studies of a first set of experimental issues, and we found no studies of a second set of issues, then we infer that psychologists believed the first set to be more important, interesting, tractable or interpretable than the second.

The two literatures quite clearly arise out of interests in substantially different underlying questions. Economists appear to be primarily interested in questions of the following sorts:

1. Can we find specific, measurable attributes of basic individual choices under risk that predict diversity in the riskiness of asset holdings as behavior that can be sustained in the presence of feedback and replication?[3]

2. Will these attributes predict sustained diversity in choice across insurance policies?[4]

3. Is the aggregate pattern of risk allocation in capital and insurance markets that is produced by such decentralized risk-bearing choices sensible? That is, how extensive are the improvements, if any, that a social planner could make if risks were borne in line with some feasible social assignment?[5]

4. Can risk be specified as a function of the probability distribution over outcomes in such a way that individuals whose rational preferences over lotteries diverge can nonetheless agree as to which lotteries are riskier?[6]

Question 3 above is beyond the focus of this study, but should be kept in mind, as it is the most basic motivation for most economic research in this area.

In constrast, the basic questions which appear to underlie psychologists' studies are more introspective, and less concerned with interpersonal comparison. It also seems to be the case that not all questions we list are concerns of all psychologists, or are even compatible with other listed questions.

1. Is there some emotional involvement with risk that leads individuals to prefer at least small amounts of risk to no risk at all?

2. In evaluating risky alternatives, do individuals weight their evaluations of the various possible outcomes under a given alternative by the true or objective probabilities of those outcomes (if known), in order to attain a combined evaluation of that alternative?

3. Does the perceived point of reference matter for risk decisions?
4. Does whether individuals seek or avoid risk depend upon whether the alternatives involve gains or losses?

2. Theoretical Approaches

2.1 Expected utility theory

The conventional economic theory of risky choice has little logical variation from the economic theory of choice. Let C be a consumption set (or set of alternatives), usually a subset of a finite-dimensional real space. Let L be the set of measures or lotteries on C, where a typical element of L specifies a probability with which any element $c \in C$ is attained. L is convex, that is, for any $x,y \in L$, $z = [\lambda x + (1 - \lambda)y] \in L$ for any $\lambda \in [0,1]$.

An individual preference ordering is an order $\succsim$ on L x L, assumed to satisfy:

A1. $\succsim$ is complete; that is, for any $x,y \in L$, either $x \succsim y$ or $y \succsim x$ (or both).

A2. For any $x,y,z \in L$, the sets $\{\lambda \in [0,1] \mid \lambda x + (1 - \lambda)y \succsim z\}$ and $\{\lambda \in [0,1] \mid z \succsim \lambda x + (1 - \lambda)y\}$ are closed.

A3. For any $x,y,z \in L$ so that $x \sim y$, $\frac{1}{2} x + \frac{1}{2} z \sim \frac{1}{2} y + \frac{1}{2} z$, where $a \sim b$ means $a \succsim b$ and $b \succsim a$.

Then, Herstein and Milnor [1953] demonstrate the existence of a real-valued utility function v on L which is order-preserving, that is, for any $x,y \in L$, $v(x) \geq v(y)$ is equivalent to $x \succsim y$, and which satisfies, for any $x,y \in L$, any $\lambda \in [0,1]$,

$$v(\lambda x + (1 - \lambda)y) = \lambda v(x) + (1 - \lambda)v(y). \qquad (1)$$

If $B(w) \subset C$ is the set of gambles which are feasible with wealth w, then utility as a function of wealth is the value function of the concave programming problem which specifies rational behavior given preferences:

$$u(w) = \max v(x) \text{ subject to } x \in B(w). \qquad (2)$$

The study of $u(w)$ when v satisfies (1) originates with von Neumann and Morgenstern [1944], and u functions which satisfy (1) are traditionally called von Neumann-Morgenstern (or vNM) utility functions.

Arrow [1965] and Pratt [1964] developed the relationship between twice continuously differentiable, vNM utility functions and risk aversion, which they proposed to measure by

$$R(u,w) = \frac{-u''(w)}{u'(w)} = -\frac{d^2u(w)}{dw^2}\left(\frac{du(w)}{dw}\right)^{-1} \qquad (3)$$

$R(u,w)$ is positive if and only if u is locally concave at w. $R(u,\cdot)$ is everywhere positive if u is concave. For individuals a and b with utility functions u_a and u_b, if $R(u_a,\cdot) \geq R(u_b,\cdot)$ for all relevant wealth levels, then u_a has in some sense "more curvature" than u_b, and a will exhibit more risk aversion behavior than b.

The canonical insurance problem is when a and b achieve wealth $w + \tilde{\varepsilon}$, where $\tilde{\varepsilon}$ is a random variable. Insurance would guarantee a or b wealth $w + E\tilde{\varepsilon} - \pi$, where π is the premium. The risk premium, π_i, the most individual i is willing to pay for such complete insurance, is defined by

$$E\{u_i(w + \tilde{\varepsilon})\} = u_i(w + E\tilde{\varepsilon} - \pi_i), \; i = a,b. \tag{4}$$

Pratt demonstrates the following theorem.

Theorem (Pratt [1964]).

The following 3 conditions are equivalent.

(i) $R(u_a,w) \geq R(u_b,w)$ for all w.

(ii) There exists a monotone increasing concave function G such that $u_a(w) = G(u_b(w))$ for all w.

(iii) For any w, any $\tilde{\varepsilon}$, $\pi_a \geq \pi_b$, as defined in (4).

The second condition is that a's utility function can be obtained by "concavifying" b's utility function. The last condition confirms our intuition: a exhibits more risk averse behavior by being willing to pay a higher risk premium than b.

The Arrow-Pratt measure of risk aversion also coincides with intuition in the canonical portfolio problem. If a and b face a choice between investing in a riskless asset yielding z or a risky asset returning $\tilde{y}$ (random), the optimal fractions of wealth invested in the risky asset, α_a and α_b, are determined by:

$$Eu_i\{\alpha_i\tilde{y} + (1 - \alpha_i)z\} \geq Eu_i\{\hat{\alpha}\tilde{y} + (1 - \hat{\alpha})z\}$$
$$\text{for any } \hat{\alpha}\varepsilon[0,1], \; i = a,b \tag{5}$$

For any $\tilde{y}$,z, for α_a,α_b defined by (5), if $R(u_a,\cdot) \geq R(u_b,\cdot)$, then $\alpha_a \leq \alpha_b$. That is, a optimally invests a smaller fraction of wealth in the risky asset than b; a's portfolio is less risky.

If the behavior of diverse individuals is to be predicted in choices over assets when no riskless asset is available, it is useful to examine when a random variable $\tilde{Y}$ is riskier than another random variable $\tilde{X}$. Rothschild and Stiglitz [1970] list four plausible answers:

1. $\tilde{Y}$ is equal to $\tilde{X}$ plus noise: $\tilde{Y} \sim (\tilde{X} + \tilde{Z})$ where $E(\tilde{Z}|\tilde{X}) = 0$, all $\tilde{X}$ ($A \sim B$ means A is distributed as B).
2. Every risk averter prefers $\tilde{X}$ to $\tilde{Y}$: if $E(\tilde{X}) = E(\tilde{Y})$ but $E\{u(\tilde{X})\} \geq E\{u(\tilde{Y})\}$ for all concave u, $\tilde{Y}$ is riskier than $\tilde{X}$.
3. $\tilde{Y}$ has more weights in the tails than $\tilde{X}$: if the density function of $\tilde{Y}$ can be obtained from the density function of $\tilde{X}$ by a mean-preserving spread of some probability mass toward the tails, $\tilde{Y}$ is riskier than $\tilde{X}$.
4. $\tilde{Y}$ has a greater variance than X.

The 4th answer does not have the intuitive support of the first 3, but is commonly used. Rothschild and Stiglitz show that the first 3 answers, in fact, coincide, inducing equivalent partial orderings on random variables taking bounded values. In terms of this common definition of increasing risk, the variance approach, which is a complete order, orders cases where $\tilde{X}$ and $\tilde{Y}$ are not comparable (neither a mean-preserving spread of the other).

In an addendum, Rothschild and Stiglitz [1972] report that their equivalence theorem is implied by Blackwell's theorem [1950] (more accessible in Blackwell and Girschick [1954], Ch. 12).

In the last two months, the first research on risk aversion when initial wealth is uncertain has appeared, Ross [1979] and Kihlstrom, Romer and Williams [1979]. This is important since complete insurance against all possible variations in wealth is not available, and yet intuition

would lead to the suspicion that the more risk-averse individual would pay a higher risk premium for partial insurance. Both of these papers, however, present examples where initial wealth is $\tilde{w}$ (random), $R(u_a,\cdot) \geq R(u_b,\cdot)$ for all w, yet the insurance premia to avoid a risk $\tilde{\varepsilon}$, unrelated to $\tilde{w}$, exhibit $\pi_a(\tilde{w},\tilde{\varepsilon}) < \pi_b(\tilde{w},\tilde{\varepsilon})$.

Ross proposes a stronger interpretation of "a is more risk averse than b" to handle cases where wealth is random. He demonstrates the following theorem:

Theorem [Ross, [1979]).

The following three conditions are equivalent.

(i) There exists a $\lambda > 0$ so that for all x,y:

$$\frac{u_a''(x)}{u_b''(x)} = \left.\frac{d^2u_a(w)/dw^2}{d^2u_b(w)/dw^2}\right|_{w=x} \geq \lambda \geq \frac{u_a'(y)}{u_b'(y)} = \left.\frac{du_a(w)/dw}{du_b(w)/dw}\right|_{w=y}$$

(ii) There exists a monotone increasing concave function G and a $\lambda > 0$ so that $u_a(w) = \lambda u_b(w) + G(w)$ for all w.

(iii) For all $\tilde{w}$, all $\tilde{\varepsilon}$ so that $E\{\tilde{\varepsilon}|\tilde{w}\} = 0$, if π_a,π_b are defined by $E\{u_a(\tilde{w} + \tilde{\varepsilon})\} = E\{u_a(\tilde{w} - \pi_a)\}$ and $E\{u_b(\tilde{w} + \tilde{\varepsilon})\} = E\{u_b(\tilde{w} - \pi_b)\}$, then $\pi_a \geq \pi_b$.

Both (i) and (ii) express a condition that u_a is, roughly, uniformly more concave than u_b. Condition (iii) is that a is willing to pay more for partial insurance, to avoid a risk that is uncorrelated with wealth.[7] Ross presents the example $u_a(w) = -e^{-Aw}$, $u_b(w) = -e^{-Bw}$, $A > B$, as a case where $R(u_a,w) = A > B = R(u_b,w)$, all w, yet (i) and (iii) above are not satisfied.

Kihlstrom, Romer and Williams [1979] deal with the smaller class of cases where the insurable risk $\tilde{\varepsilon}$ is distributed independently of (not just uncorrelated with) $\tilde{w}$. They show that if $R(u_a,w) \geq R(u_b,w)$, all w, and either side of this equation is nonincreasing in w, then $\pi_a \geq \pi_b$ as defined above (assuming $\tilde{\varepsilon} \sim (\tilde{\varepsilon}|\tilde{w})$, that is, knowing the realization of $\tilde{w}$ doesn't alter distribution of $\tilde{\varepsilon}$). An example if presented to demonstrate that the nonincreasingly-risk-averse condition is critical.[8]

In Ross' model and in the Kihlstrom et al. model, the conditions which imply $\pi_a \geq \pi_b$ are sufficient to demonstrate that a chooses a less risky portfolio than b, in the more realistic situation where there is no risk free asset. For example, suppose there are two assets yielding random rates of return $\tilde{x}$ and $\tilde{y}$, where $\tilde{y} \sim \{\tilde{x} + \tilde{z} + \tilde{\varepsilon}\}$, $\tilde{z} \geq 0$ is the added return for investing in $\tilde{y}$, and $\tilde{\varepsilon}$ is the additional risk. Assume

$$E\{\tilde{\varepsilon}|\tilde{x} + \tilde{z}\} = 0.$$

In addition, for the Kihlstrom et al. context, $\tilde{\varepsilon} \sim \{\tilde{\varepsilon}|\tilde{x} + \tilde{z}\}$. Now if the proportion of wealth invested in the riskier asset $\tilde{y}$ is α_a,α_b defined by

$$E\{u_i(\alpha_i\tilde{y} + (1 - \alpha_i)\tilde{x})\} \geq E\{u_i(\alpha\tilde{y} + (1 - \alpha)\tilde{x})\}, \text{ all } \alpha\varepsilon[0,1], \ i = a,b$$

then $\alpha_a \leq \alpha_b$ in either model.

2.2 Portfolio theory

The psychological theories of decision under risk appear to have been introduced as a direct consequence of dissatisfaction with expected utility theory. Coombs [1975] develops an alternative he calls portfolio theory (a terminological choice confusing to economists), clearly a culmination of earlier work by him and others, referenced therein.

Portfolio theory is defined directly on a set of gambles $G = \{A, B, C, \ldots\}$[9] "with numerical probabilities and monetary outcomes," and takes as primitive concepts two binary relations on G, $\succsim_p$ and $\succsim_r$. $\succsim_p$ is a preference relation, and $\succsim_r$ is a risk relation which is unspecified; $A \succsim_r B$ implies that A is riskier than B for some measure of risk. While Coombs does not specify, the context suggests to us that $\succsim_p$ is thought to be individual-specific, and $\succsim_r$ to be common across individuals. Also, $\succsim_p$ and $\succsim_r$ must both be complete orders for the logical operations Coombs performs to be valid.

Coombs structures $(G, \succsim_p, \succsim_r)$ by assuming the existence of a risk preference scale $\phi(t,x)$, where t is an expectation level, and $X \in G$ with $E(X) = t$, satisfying:

1. Order preservation: If $E(A) = E(B) = t$, then $A \succsim_p B$ if $\phi(t,A) \geq \phi(t,B)$.
2. Single-peakedness: If $E(C) = E(B) = E(A) = t$ and $C \succsim_r B \succsim_r A$, then either $\phi(t,B) \geq \phi(t,A)$ or $\phi(t,B) \geq \phi(t,C)$.
3. Dominance: If $E(A) = a \geq b = E(B)$ and $\phi(a,A) \geq \phi(b,B)$, then $a \succsim_p B$. Moreover, if either inequality is strict, $B \not\succsim_p A$.

In addition, Coombs assumes "risk invariance": If $E(B) = E(A)$ and $K \sim \text{Prob}\{K = k > 0\} = 1$, then $B \succsim_r A$ if $B + K \succsim_r A + K$.

Behavior then follows $\succsim_p$. A is chosen over B if $A \succsim_p B$, and is chosen from the set $S \subset G$ if $A \succsim_p B$ for all $B \in S$. In particular, if $E(B) = t$ for all $B \in S$, $A \in S$ is chosen if $\phi(t,A) \geq \phi(t,B)$, all $B \in S$.

If choosing over alternatives with different means, Coombs theorizes that an individual balances a tradeoff between mean and deviations from

the ideal level of risk. Suppose, in addition, that, for any A,B with $E(A) = E(B)$, if $A \succsim_r B$, then $A \succsim_r \lambda A + (1 - \lambda)B \succsim_r B$, for any $\lambda \in [0,1]$. Then if A is less risky than the individual would like, and B is more risky than desired, for some λ, $\lambda A + (1 - \lambda)B \succsim_p A$ and $\lambda A + (1 - \lambda)B \succsim_p B$, which is not possible in expected utility theory. (Note that expected utility maximization satisfies Coomb's theory.)

In postulating a complete risk order $\succsim_r$, which is left unspecified, Coombs is apparently relying upon Pollatsek and Tversky [1970], who set out to develop a measure of risk based upon distributions of lotteries. They provide axioms which imply the existence of an order-preserving risk function, which under further assumptions is shown to be a linear combination of mean and variance (unique up to scale).

Pollatsek and Tversky present arguments for the plausibility of some of their assumptions, but not for the assumption that there is a complete order on the set of lotteries interpretable as increasing risk--this they view to be innocuous. In light of the work of Rothschild and Stiglitz [1970] and Blackwell [1950] discussed above, this assumption is so severe as to raise the question of whether their theorem is vacuous. Coombs, of course, also uses a complete order $\succsim_r$, and faces this same possible inconsistency.

2.3 Prospect theory

Kahneman and Tversky [1979], which has just recently come to our attention, is a presentation of experimental evidence which leads the authors to reject the validity of expected utility theory, and of a theory designed to be consistent with this evidence.

In prospect theory, the choice process consists of two phases: first editing and then evaluation. A prospect $(x_1, p_1; \ldots, x_n, p_n)$ yields outcome x_i with probability p_i, and, for simplicity, 0 with probability $(1 - \sum_{i=1}^{n} p_i) \geq 0$.

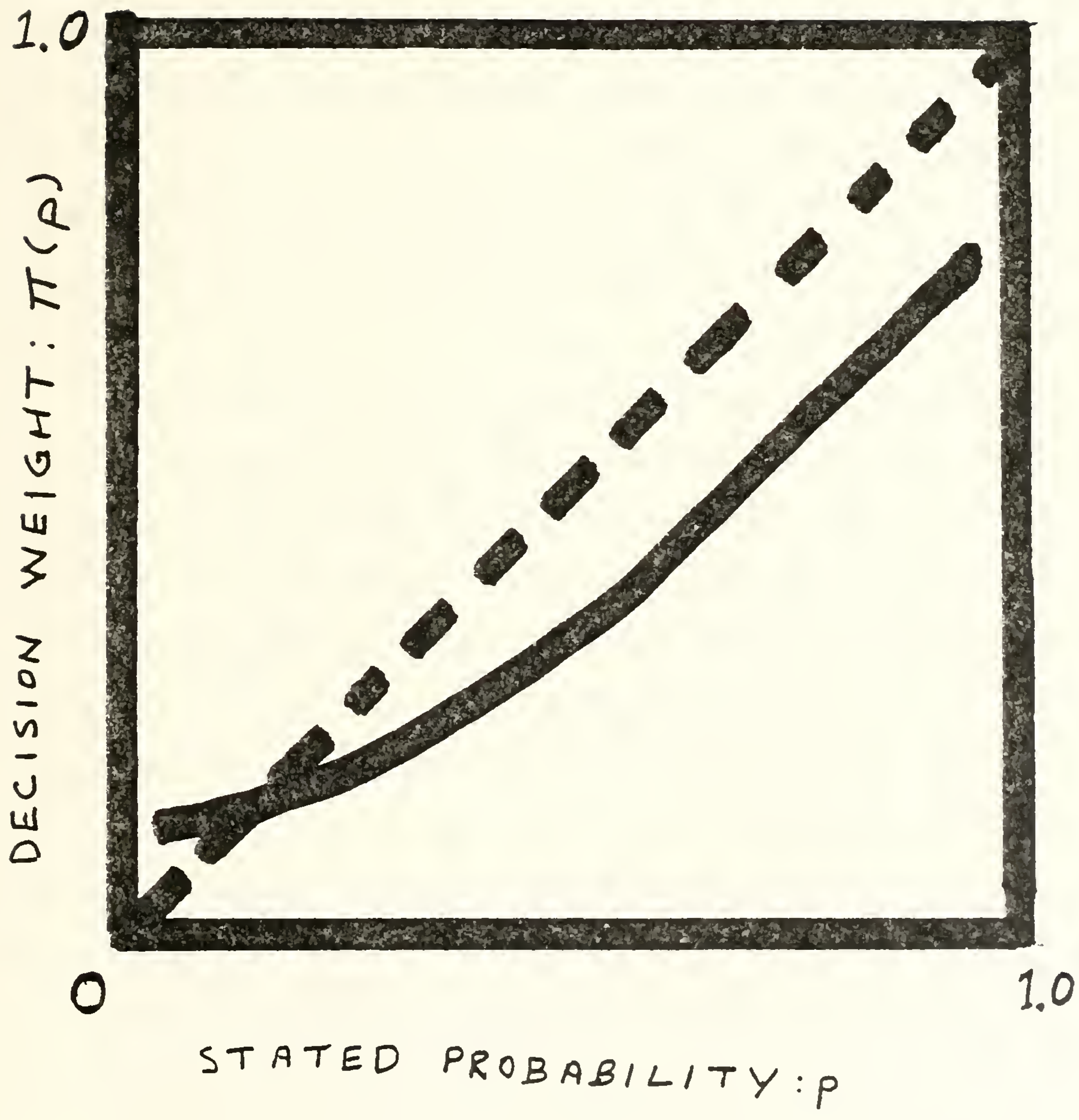
The editing phase of the choice process is not precisely specified, but described to include such activities as encoding prospects in terms of gains and losses rather than final wealth, simplifying compound lotteries, rounding off $(x_i, p_i) = (101, .0993)$ to $(100, .1)$, etc. Where the editing phase creates inconsistencies, these are presumably of limited consequence.

The evaluation function for the edited prospect $(x,p; y,q)$ is

$$V(x,p;\ y,q) = \begin{cases} \pi(p)v(x) + \pi(q)v(y), & \text{if a} \\ v(y) + \pi(p)[v(x) - v(y)], & \text{if b} \end{cases}$$

where a is the case $[p + q < 1$ or $x \geq 0 \geq y$, or $x \leq 0 \leq y]$ and b is the case $[p + q = 1$ and either $x > y > 0$ or $x < y < 0]$. If the weighting function π exhibited true probabilities ($\pi(p) = p$, all p), this would be equivalent to maximizing expected utility with v as the utility function.

However, Kahneman and Tversky theorize that $\pi(p) = p$ occurs rarely. $\pi(0) = 0$, as "impossible events are ignored,"[10] and $\pi(1) = 1$ by normalization. However, $\pi(p)$ is a monotonic function flatter than $f(p) = p$, and discontinuous at 0 and 1. $\pi(p) + \pi(1 - p) < 1$ for all $p \in (0,1)$, and $\pi(p) > p$ for very small p. Above some rather small value, $\pi(p) < p$. Figure 1 shows a graph of $\pi(p)$. Finally, $\pi(p)$ is flatter near 0: if $\pi(p)v(x) = \pi(pq)v(y)$, then $\frac{\pi(pq)}{\pi(p)} \leq \frac{\pi(pqr)}{\pi(pr)}$, $0 < p,q,r \leq 1$. That is, relative to given odds of obtaining x, if a more favorable outcome y is


1.0
DECISION WEIGHT: $\pi(p)$
0
1.0
STATED PROBABILITY: p

just enough less probable to create indifference, proportionate reductions in odds destroys this indifference, leading one to favor the smaller chance of a greater return.

Kahneman and Tversky further believe that v does not behave like a concave utility function. v is defined for gains and losses from an initial reference point, is concave for gains, convex for losses, and steeper for losses than for gains.

Thus, choices diverge from expected utility maximizing choices in the underweighting of all but very small probabilities (and certainty), and in risk-seeking for losses.

In transactions where one pays money for a desirable prospect, Kahneman and Tversky hypothesize that the prospect and its cost are evaluated separately. That is, if the prospect (1000, .01) were available for a cost of 10, rather than contrasting (990, .01, -10, .99) to (0), the individual contrasts (1000, .01) to (-10). This makes the prospect less attractive, given their theory.

The following quote vividly illustrates the contrast of their theory with the economic approach:

> . . . we are compelled to assume that values are attached to changes rather than to final states, and that decision weights do not coincide with stated probabilities. These departures from expected utility theory must lead to normatively unacceptable consequences, such as inconsistencies, intransitivities, and violations of dominance. Such anomalies of preference are normally corrected by the decision maker when he realizes that his preferences are inconsistent, intransitive, or inadmissible. In many situations, however, the decision maker does not have the opportunity to discover that his preferences could violate decision rules that he wishes to obey. In these circumstances the anomalies implied by prospect theory are predicted to occur.[11]

3. Explanations of Behavior

The coexistence of gambling and insurance is widely regarded as a key paradox for a theory of risk choice to explain. Portfolio theory

explains gambling by suggsting that the gambler prefers some risk to none at all, and is willing to sacrifice expected value to obtain some risk. It has some difficulty explaining insurance, for not buying insurance would also give the individual some risk. The theory is forced to suggest that not buying insurance would leave the person with more than the ideal risk, but placing amounts roughly comparable to insurance premiums on low-probability, high-payout gambles would be inconsistent with buying insurance. Portfolio theory is more comfortable with the person who buys insurance only against major (low-probability) catastrophes, and bets \$1 on a $\frac{1}{3}$ chance to win \$2.80.

Prospect theory has some difficulty with both insurance and gambling. Gambling is modelled as involving low-probability gains, over which people are risk-averse. Insurance involves avoiding low-probability losses, but people are risk seekers when it comes to losses. And the gambling wins or insurable hazards are evaluated separately from the ante or premium, which gets overweighted because it is certain.

Thus, propsect theory must rely upon overweighting of very small probabilities to overcome what would otherwise be a strong prediction that gambling and insurance would be unchosen alternatives. In particular, this theory is more comfortable with insurance only against very low probability events, and such gambling as state lottery tickets, or betting on horses who seldom win.

The expected utility explanation of gambling and insurance is less strained in elucidating diversity of gambling and insurance choices across people. Insurance against any variation $\tilde{\varepsilon}$, low probability or not, available for cost c is purchased if $\pi(\tilde{\varepsilon},\tilde{w}) \geq c$, if this risk premium the individual is willing to pay exceeds the cost. More risk averse

people will be seen insuring against less risky contingencies, and insurance against major wealth changes will sell to a wider market.

There seems to be a common conception among psychologists that gambling is inconsistent with expected utility maximization. We consider this a misconstrual of the theory. Recall that utility is a function of consumption lotteries, derived from preferences over probability measures on the consumption set. Utility of wealth is defined as the utility of the utility-maximal consumption vector obtainable with that level of wealth.

Gambling is not an investment activity for the representative consumer who gambles, but a consumption activity, like eating a mango, riding in a speedboat, or employing the services of a prostitute. The consumer gambles because the combination of attributes so consumed--the risk involved, the personalities and interaction, the attention he receives, the physical setting, and the emotional impact of all these factors--is preferred to alternative consumption possibilities.

It is true that good or poor luck in gambling will affect the amount of resources which the gambler can devote to other consumption activities. But this is also the case when an individual does not know how many stores he will have to visit to obtain an item with a known price but unknown availability. Visiting stores in such a case is not a contradiction to expected utility maximization.

Gambling would only be a contradiction of expected utility maximization if all the valued consumption attributes were available in some alternative risk-free consumption activity. Since some of these consumption attributes depend upon risk to be enjoyable for the individual, this is not a conceivably available alternative.[12]

4. Methodology

4.1 Hypothetical choices

The prevalent methodology in psychological studies of decision under risk is well-known. Subjects in experiments are in effect surveyed, asked to divulge the hypothetical choices they would make if actually faced with a specified choice problem, presented in questionnaire form.

In some cases subjects are asked to make choices from up to 120 pairs or triples of alternatives. Kahneman and Tversky [1979] reduced or eliminated fatigue effects by limiting the number of choices made to 12.

They support this methodology as being preferable to feasible alternatives:

> The reliance on hypothetical choices raises obvious questions regarding the validity of the method and the generalizability of the results. We are keenly aware of these problems. However, all other methods that have been used to test utility theory also suffer from severe drawbacks. Real choices can be investigated either in the field, by naturalistic or statistical observations of economic behavior, or in the laboratory. Field studies can only provide for rather crude tests of qualitative predictions, because probabilities and utilities cannot be adequately measured in such contexts. Laboratory experiments have been designed to obtain precise measures of utility and probability from actual choices, but these experimental studies typically involve contrived gambles for small stakes, and a large number of repetitions of very similar problems. These features of laboratory gambling complicate the interpretation of the results and restrict their generality.
>
> By default, the method of hypothetical choices emerges as the simplest procedure by which a large number of theoretical questions can be investigated. The use of the method relies on the assumption that people often know how they would behave in actual situations of choice, and on the further assumption that the subjects have no special reason to disguise their true preferences. If people are reasonably accurate in predicting their choices, the presence of common and systematic violations of expected utility theory in hypothetical problems provides presumptive evidence against that theory.[13]

There are several reasons to be more skeptical of hypothetical choices data than are Kahneman and Tversky.

1. In any choice situation complex or subtle enough to be worthy of investigation, people do not automatically know how they would behave since decision reaching is a matter of calculation, which is a costly activity. Subjects can be expected to economize in their use of time and mental activity just as with other scarce or valuable resources. When subjects do not have adequate incentive to calculate a correct representation of their behavior, it is hazardous to draw research conclusions from their exhibited choices.

2. It is naive to believe that subjects have preferences over behavioral choices (the reasons for experimenting), but do not have preferences over reported choices to experimenters. There are several reasons why a subject might report choice A rather than choice B to an experimenter: a) the subject actually would choose A in the situation being represented, b) the subject chose A randomly, perhaps because random choice was the result of a rational decision not to calculate a comparison of A and B,[14] c) the subject chose A because more money was made with A than with B, d) the subject chose A because (s)he derives enjoyment from actions thought to assist the experimenter, and/or e) the subject reports choice A in order to impress the experimenter with his/her intelligence, boldness, or other ability or trait.

In general, several of these reasons may be relevant, and which are most important may determine the response.

3. When subjects are not motivated by payment in accordance with their choices, experimenter effects may be an important factor in their willingness to volunteer for the experiment originally. Seldom does an individual volunteer for an unpaid choice experiment out of a burning desire to reveal the truth, unless this desire is closely connected to a desire to help out the experimenter with his research.

4. Without financial motivation, there is little scope for the experimenter to alter the "terms of trade" among the various reasons for subjects to choose one response over another. He may alter the experiment so as to make calculating true responses require somewhat less exertion, but any significant easing of calculations will sometimes interfere with what he hopes to learn. Minor effects could result from making the subject's task more interesting, and less repititious, but again the investigation intended will leave little scope for this.

While an experimenter can be careful to word instructions in a neutral manner, and to avoid letting subjects discern preexperimental hypotheses, without financial motivation, desire to assist him will usually be the primary reason for subjects volunteering. Thus, they may put more effort into attempting to determine what response is most helpful than into determining what response is most truthful.

5. Kahneman and Tversky's criticism of financial motivation experiments is directed to experiments they have seen reported, not to the potential of the technology. If contrived gambles for small stakes will not reliably discern data, this is an argument that scientific experimentation is expensive, not that it is impossible.

A major advantage to an experimental methodology which pays or rewards subjects in accordance with performance (by actually running the lotteries they choose), is that the experimenter does have the flexibility (at cost) to control other reasons why subjects may prefer one response to another. If a given monetary difference (certain or expected) between choices A or B is not enough to exceed costs of calculation, revive interest, or outweigh a preference for bold actions, the monetary difference can be increased. This is almost always possible without interfering with the phenomena which the experimenter wishes to observe or measure, and without introducing any untoward experimenter effects. Careful research will usually be expensive.

There is substantial experimental evidence that significant variability in subject payments can dramatically influence results.[15] These considerations prevent us from concluding that economically valid implications can be drawn from hypothetical choice experiments.

4.2 Proposed methodology.

This section outlines the methodology used in a pilot study performed by the authors in March and April 1979.[16] Extreme budgetary restrictions forced some compromises, and the novelty of the use of this methodology to study these questions entailed learning on our part as

the study progressed. Nonetheless, the report to follow indicates the type of information obtainable and the degree of reliability involved in reasonable stakes experiments, which we believe contrast quite favorably with the hypothetical choices studies.

4.2.1 Wealth effects and variation

The Arrow-Pratt measure of risk aversion cannot directly be observed in the laboratory with currently feasible technology. Direct observation that subject a is more risk averse than subject b in Ross' sense is beyond conceivable technology. However, the equivalence theorems of Pratt and Ross provide a method of observation.

If subject a exhibits willingness to pay a higher risk premium than b is willing to pay to avoid a wide enough variety of insurable risks, at a wide enough variety of wealth levels, the theory allows us to conclude that a is more risk averse than b.

The theory then yields the testable implication that a, being more risk averse than b, will select a less risky portfolio, in an investment problem where cash rewards are in proportion to profits or losses.

It is, however, prohibitively expensive to substantially juggle the wealth of subjects in order to determine risk premia at varying wealth levels. It is also inconceivable with all but the most myopic subjects, as subjects would quickly realize that the wealth level to which the experimenter has boosted them is not the wealth level at which they will end the experiment (another wealth level change is anticipated as soon as the subject exhibits risk tolerance at this wealth level), and so the purpose would be defeated.

As a result, the risk premium information obtained at a single wealth level must suffice to discern risk aversion level, at least over a wealth range sufficient to test the theory in a portfolio selection simulation. The following precept enables single-wealth-level testing.

PRECEPT. An experimental subject facing risky choices evaluates possible cash outcomes in terms of some utility function which can be approximated over a relevant range by $u(w,c) = -e^{-kw} - f(c)$, where k is an individual-specific constant, w is final wealth, f is increasing, c represents costs of calculating and information processing.

This supposes locally constant absolute risk aversion in the Arrow-Pratt measure. Ross [1979] uses this case for his counterexample, showing that there are risks $\tilde{\varepsilon}$, uncorrelated with wealth $\tilde{w}$, which exhibit the less risk averse individual willing to pay a higher risk premium to avoid $\tilde{\varepsilon}$. However, the theorem of Kihlstrom et al. [1979] covers this case, so none of Ross' examples involve $\tilde{\varepsilon}$ independent of $\tilde{w}$.

This does make it vital that the experimental design generate risks truly independent of wealth. For example, particular abilities, skills, or traits which may lead to higher or lower wealth should not spread or contract the distribution of earnings in the experiment.

4.2.2 Experimental design and procedures

Five experimental sessions were run in Champaign, involving 18 subjects, at most four per session. We used the deductible on automobile collision insurance as evidence of risk aversion. Consequently,

subjects were recruited who had made their own decision on auto insurance. Subjects were largely students, but four other occupations were represented.

Sessions began by recording subject names and social security numbers for files separated from experimental data. Subjects were placed at tables about 10 feet apart in view of a blackboard, and did not communicate with each other. Subjects filled out a chance bets questionnaire and read instructions (both are in the appendix). Any questions not dealing with strategy were answered.

As the appendix specifies, subjects were given a 36-'week' price history for seven stocks, labelled with Greek letters. They were to manage a $10,000 portfolio to be invested in any or all of the stocks, and to choose the amount of the portfolio to be 'saved,' earning 0.1%/'week' with certainty. A 1% commission was charged on all stock transactions. The portfolio could be reselected in each of the next five weeks. Subjects would be paid $10 plus 1 1/2% of profits on the portfolio plus earnings from whichever chance bet they chose in a pair picked at random.

When instructions were clear, one of the authors sat down next to each subject, to serve as an assistant for calculating and recordkeeping. We were aware of the possibility that this would add obtrusion effects, but felt that the effects of reducing boredom by handling calculations, and of ensuring accurate records, outweighed any such problems. We were careful to be neutral,[17] and to avoid all expressions of approval, surprise, etc.

When each week's purchases, sales and savings had been chosen by the subject and recorded by the experimenter, the next week's prices

were posted on the blackboard. After the final prices were posted, the value of their portfolio and their 1 1/2% earnings were calculated. Then the chance bet pair for each subject was chosen at random, whichever bet the subject had selected run, earnings calculated and paid in cash. The collison insurance deductible was recorded (or value of car if subject did not have collision insurance), and subjects were dismissed. The same stock prices were never reused.

5. Hypotheses and Results

The primary concern of our empirical work is with attempting to predict the portfolio risk that people would assume in the experiment outlined above. In particular, we wish to test whether subjects who exhibit more risk aversion in their automobile insurance and chance bets decisions will display the same risk aversion in portfolio choices. Such a finding would be consistent with expected utility maximization. Denial of this finding would weaken the foundations of asset pricing theories based on the maximization of expected utility, where the utility function incorporates underlying attitudes toward risk.

The theory of the earlier section seems to relate equally well to predictions of chance bet outcomes, deductibles on auto insurance, and risk of portfolios. Yet this paper concentrates on predicting portfolio risk. Why, then is portfolio risk the focus here?

There are several answers to this question. First, the theory developed above does not equally apply to all measures. While it has been shown that a high risk premium for auto insurance and chance bets implies a high level of absolute risk aversion which, in turn, implies

a low risk portfolio, the reverse implication has not been proven.[18] Thus, there is some theoretical reason for using portfolio risk as a dependent variable.

Furthermore, there are several more practical reasons for doing so. For one, the majority of the risk in the economy is diversified through capital markets;[19] thus, the portfolio choices in these markets are of primary importance. Furthermore, the portfolio choice in the experiment seems to be much less subject to outside influence than the other choices. Insurance choices are subject to moral hazard and information assymetry problems which are not present in the experiment. The fact that auto deductibles can not, in general, assume a continuous range of values also presents measurement error problems. Chance bets provide a weak measure of risk attitudes because of calculation costs and other problems, as has been described above (and will be shown below). Thus, portfolio choices, where subjects have access to the same information, provide the "cleanest" measure of risk preference available.[20]

Our hypothesis boils down to a statement that portfolio risk should be positively related to the risk displayed in auto insurance and chance bet decisions. Testing this hypothesis requires measures of risk for the various decisions. The variable proxies to be used are the following:

PR - Portfolio risk is measured as the variance of return in a subject's portfolio averaged over the six weeks of choices. This is, thus, computed as

$$PR = \sum_{j=1}^{6} \frac{1}{6} \sum_{k=1}^{8} w_{jk}^2 \sigma_k^2$$

where j is an index for weeks, k is an index for securities, w_{jk} is the proportion of one's week j portfolio invested in asset k, and σ_k^2 is the variance of return on security k.[21] No covariance terms are needed here since all returns are independent.[22]

The use of this PR variable as opposed to the average standard derivation or others, is motivated by a look at terminal wealth variance. In this experiment, terminal wealth will be

$$W_T = (1 + r_1)(1 + r_2)(1 + r_3)(1 + r_4)(1 + r_5)(1 + r_6)W_0,$$

where r_i is rate of return in period i, W_0 is original wealth. If the r_i's are independent, $\mathrm{var}(r_i) << 1$, and $\sigma(r_i) \approx 0$, then

$$\mathrm{Var}(\frac{W_T}{W_0}) \approx \sum_{i=1}^{6} \mathrm{Var}(r_i).$$[23]

These assumptions hold approximately here.

CB - The chance bets risk premium was measured as the minimum amount of extra expected value necessary to induce a subject to take a riskier bet. (The riskier bet here was a 60% chance of winning \$x and a 40% chance of losing \$x-5. The less risky bet was a 80% chance of winning 5¢ and a 20% chance of losing 10¢.) Where a subject displayed inconsistent choices in chance bet selection, the minimum amount of expected value he required to consistently select the riskier bet was used. Only one subject displayed such inconsistency.

DED - The deductible variable is measured as the deductible value on the collision insurance of the subject's auto insurance policy.

In the process of running the experiment, a problem with DED arose. Three subjects had no collison insurance at all. The effective deductible for these people is the value of their car, since this is the maximum collision damage they can suffer. Thus, for people with no collision insurance DED was set equal to their estimate of the value of their car.

The test of the hypothesis offered above was first attempted through the following regression equation:

$$PR = b_0 + b_1 CB + b_2 DED.$$

The linear functional form was attempted since it seemed the simplest, and the theory offered little guidance in selecting a form. The results of the regression run on the 18 observations in the sample (with t-statistics in paretheses) is

$$(1)\quad PR = 5.04 - \underset{(.89)}{.374}\ CB + \underset{(2.85)^*}{.00878}\ DED$$

$$R^2 = .35 \qquad F = 4.07^*$$

The * is used throughout to designate significance at the 5% level, ** at the 1% level, and + at the 10% level in a 2-tailed test.

This particular specification was thought to capture the intended effects imperfectly. Two specific problems remained. The less important one involved the change of the price series used in the third run of the experiment. That is, for the first 8 subjects, the price series had a zero average rate of return i for the remaining 10 subjects, the series had a mean rate of return of .2% per week. This change could possibly have influenced subjects to take more risk.

The more important problem involved measurement of auto insurance risk. The implicit assumption in this paper is that the observed deductible represents the desired risk position of the individual, given the premiums involved. This may not be true, especially for those with no collision insurance. These "uninsured" subjects are likely not to have desired the "full" risk of car value, but were unable to find offers of any deductible in excess of $250. They were either forced to assume less risk than desired ($250) or more risk (full value). For this reason, the "uninsured" subjects' deductible variable is measured with bias, an upward bias in particular.

This bias suggested that equation (1) was not a correct specification for the uninsured. They should show less risk than the regression equation would predict. This lower risk could show up through differences in either the constant term b_0, or the deductible coefficient b_2. To correct for this problem in this small sample, then, two variables were looked at.

IDUM - Zero for all those with collison insurance. One for those without.

DUMI - This is IDUM times the value of the car owned. It will thus be the value of the car owned by the uninsured and zero otherwise.

If the influence of the bias is through the constant term, the coefficient on DUMI should be negative. If the influence is through the DED coefficient, the coefficient on IDUM should be negative. The results of regression using these new variables separately were

$$\text{(2)}\quad PR = 5.14 - \underset{(.73)}{1.87\ CB} + \underset{(3.40)^{**}}{.0165\ DED} - \underset{(1.95)+}{12.2\ IDUM}$$

$$R^2 = .49 \qquad F = 4.50^*$$

$$\text{(3)}\quad PR = 2.37 - \underset{(.01)}{.0356\ CB} + \underset{(1.94)+}{.0265\ DED} - \underset{(1.33)}{.0168\ DUMI}$$

$$R^2 = .42 \qquad F = 3.44^*$$

An alternative method to get around this measurement problem is, simply, to exclude all observations of those without collision insurance. Since there were three such subjects, the sample size was reduced to 15. Because these people were extreme observations in both the deductible and portfolio risk data, much of the variability in these variables is removed by this exclusion. The result of a regression on the 15 observations is

$$\text{(4)}\quad PR = 3.47 + \underset{(.04)}{.0822\ CB} + \underset{(1.90)+}{.0216\ DED}$$

$$R^2 = .24 \qquad f = 1.88$$

To correct for the price series return problem another dummy variable was introduced:

PSER - Zero if a zero mean return price series was used. One if a .2% weekly mean return was used.

The previous 4 regressions were rerun with the PSER dummy added. The results were

$$\text{(1')}\quad PR = 7.59 - \underset{(.60)}{1.63\ CB} + \underset{(3.25)^{**}}{.0102\ DED} - \underset{(1.43)}{4.49\ PSER}$$

$$R^2 = .43 \qquad F = 3.59^*$$

$$(2') \quad PR = 6.97 - \underset{(.97)}{2.57\ CB} + \underset{(3.40)^{**}}{.0164\ DED} - \underset{(1.64)}{10.5\ IDUM} - \underset{(1.06)}{3.24\ PSER}$$

$$R^2 = .53 \qquad f = 3.69^{*}$$

$$(3') \quad PR = 5.15 - \underset{(.38)}{1.07\ CB} + \underset{(1.45)}{.0215\ DED} - \underset{(.78)}{.0111\ DUMI} - \underset{(.93)}{3.29\ PSER}$$

$$R^2 = .46 \qquad F = 2.77+$$

$$(4') \quad PR = 5.77 - \underset{(.33)}{.831\ CB} + \underset{(1.43)}{.0174\ DED} - \underset{(.96)}{2.63\ PSER}$$

$$R^2 = .30 \qquad F = 1.55$$

6. Discussion of Results

The pre-experimental hypothesis tends to be supported, although not conclusively, by the data. The primary predictions of the hypothesis concern the coefficients of the CB and DED variables. The first should be negative and the second should be positive. DED is consistently and positively related to portfolio risk. The only equations where it is not significant at the 10% level are (3') and (4'). In (3'), collinearity with DUMI has clouded the results (notice that at the 10% level, no coefficient t is significant, but the F of the regression as a whole is significant). The PSER variable also added to the collinearity. In (4'), the reduction in observations and the exclusion of extreme values has also contributed to the apparent insignificance. Considering the overall paucity of data, the strength of the DED variable and its positive coefficient are extremely encouraging for the "consistent-risk-aversion" hypothesis.

The CB variable, on the other hand, seems to have no relation to portfolio risk. The conclusion we draw from this is that careful

consideration of chance bets was not worth many subjects' cost of calculation. The selection of chance bets seemed to be more strongly influenced by the subject's facility with expected value calculations than by his risk aversion. Furthermore, the fun of betting (a consumption activity) sometimes was overriding here, because of the small gains and losses involved. These considerations would increase the noise in the CB proxy for risk preference, and thus reduce the significance of the CB coefficient.

For an indication of how serious the cost of calculation problem may have been, consider the specific bets offered. The average difference in expected value between the pairs of chance bets was 75¢. Thus, a risk neutral individual would gain 37 1/2¢ on average from calculating, as opposed to randomly choosing chance bets. Since there were 12 chance bets, of which only one was selected, this reduces to a 3.1¢ gain per decision. If the cost of calculation exceeded 3.1¢, a correct decision would be too costly for this person. This does not seem to be an insurmountable sum, even with calculators available. This average gain could also easily be dominated by other considerations like gambling thrills.

It is also encouraging to find the added variable IDUM and DUMI performing as expected with a negative sign. Since their signs are something of a post-experimental hypothesis, or at least a during-the-experiment hypothesis, we can not claim to have tested any hypothesis here. Only new data can test such a hypothesis.

It is interesting to note that the IDUM coefficient seems to perform better than the DUMI. Thus, it appears that uninsured subjects

risk preference differs from those insured mostly through an intercept change rather than a slope change in the deductible coefficient. Again, this presumption can only be tested with more data. Notice also, that DUMI may be more troublesome in creating a greater degree of multi-collinearity in the data. In fact, it is somewhat disturbing that a respecification from DUMI to IDUM should make such a great difference to the coefficients and their significance levels.

The PSER variable performs in a perverse manner in these regressions, although it is never significant. That is, when expected return went up on risky assets, portfolio risk was reduced. Our conclusion here is that it was difficult for subjects to discern any difference in the mean return of the price series, with such small differences and so much more involved. It is likely that prior beliefs about differences between risky and non-risky stock returns were far more important than the data here.

Overall, the results are encouraging. With so little data and so many measurement problems, the relationship between deductibles and portfolio risk is still highly significant. The fact that 30-50% of the variance in portfolio risk is explained in these equations suggests that risk aversion preferences exert a significant influence on portfolio choice.

6.1 Further tests

Although not yet done in the present study, at least two other interesting propositions could be tested with this data. One would concern whether subjects would hold a mean-variance efficient risky portfolio. In the return generation process used here, where all risky security returns are independent and have the same mean, the fraction

invested in any asset should be inversely proportional to its variance. That is, for a mean-variance efficient portfolio, the fraction of one's risky assets invested in security j should be

$$x_j = \frac{[\mathrm{Var}(R_j)]^{-1}}{\sum_k \{[\mathrm{Var}(R_k)]^{-1}\}}$$

where R_j and R_k are the returns on securities j and k respectively.

It would be interesting to see if subjects pick portfolios anywhere close to efficient or converge toward this with stochastic feedback. The efficient portfolio selection hypothesis could be tested against a naive alternative hypothesis of some sort, perhaps that individuals investment in securities is without regard to variance, and thus should be on average equal across securities.

A second proposition would concern the influence of price histories on expectations of future returns. The efficient markets literature would suggest that price histories have no influence on future returns, and certainly this is true of our generated data. However, several portfolio (technical) analysts have suggested filter rules (buy a stock that rises x%, sell it if it falls x%) as a way of "beating the market." A fundamental analyst, on the other hand, might suggest that a security has a "true" value and the price will tend to revert to that value. Thus, when the price is low, one should buy; when the price is high, one should sell (here high and low are defined relative to true value).

The portfolio selections in the present study can be used to see if either theory is implicitly followed by the subject. Do they use filter rules and buy (sell) stocks that have recently risen (fallen)? Or, do they buy (sell) stocks that have fallen (risen) in price, as the mean reversion theory of the fundamentalists would prescribe? Or,

as a third alternative, do they ignore past price history in selecting stocks, as the efficient marketers would suggest? While this particular test has not explicitly been done, a casual look at the data suggests a mean reversion, "buy low, sell high" belief by subjects.

A general word of caution is necessary about applying the result derived with experimental subjects to capital asset pricing problems. The "price-makers" in the capital market learn the laws of economics and probability through practical experience. Their costs of calculation are likely to be low. For this reason, they are apt to behave differently, and probably more in accordance with theory, than randomly selected subjects. Thus, a conclusion regarding pricing derived from subject behavior in experiments is on somewhat shaky ground.

7. Suggested Extensions and Conclusions

The type of research done in this study has been interesting, but also expensive. Aside from the subject payment costs, the researchers themselves are forced to expend large amounts of time in the execution of the experiment. Despite this, significant improvements to the study could be made through increased expenditures on time and money.

The two key weaknesses of the research to date is the shortage of data and the lack of wealth variation that could feasibly be studied. The 18 observations in this study are obviously not a sufficient base for any firm conclusions. In fact, it is remarkable that such a small sample has provided as much information as we have found. More data would not only provide stronger testing of the pre-experimental hypotheses already investigated, but would enable the post-experimental hypotheses to be tested on independent data.

The study, additionally, was able to look at only small wealth changes in the experimental setting. No subject earned more than $30 in the experiment overall, thus significant changes in wealth were virtually impossible. Furthermore, since the law would not allow us to take money away from subjects, no subject attitudes towards monetary losses (in the Kahneman-Tversky sense) could be tested. With greatly increased monetary payouts, attitudes toward risk could be ascertained with less reliance upon the precept in section 4.2. Higher stakes would provide more confidence that results are free from influence of extraneous factors like cost of calculations.

In particular, it is difficult to get localized information on risk from auto insurance deductibles, since deductibles may only be available in increments as large as $250. It would be quite useful if wealth variations possible in the portfolio choices were of a comparable order of magnitude to the deductible increments.

If we receive funding for further studies, we suspect the most cost-effective way to data over signficant wealth variation is the following. About 4 or 5 subjects are used in each trial. All are told in advance that one of them will be chosen at random following the experiment. The one chosen is paid in accordance with the high payment schedule, and all others are paid a fixed sum. The high payment schedule is on the order of $50 plus 10% of profits on a $10,000 portfolio. Presumably each subject evaluates risks of various portfolios in terms of the high payment schedule, yet the cost associated with it occurs only once per session.[24]

A wide variety of problems, other than those studied here, could be examined in a framework similar to ours. An important extension

could be made if individuals were given different information than that given here, to look at information effects on portfolio decisions. Summary statistics could be made more easily available to subjects to reduce costs of calculation. Nonzero covariances between security returns could be introduced to examine the influence of covariance on portfolio selection.

Another class of problems that could be looked at is the portfolio decision under asymmetric information. Such problems present tremendous difficulties for tractable theoretical modelling, and experimental evidence could direct theory. The circumstances under which equilibrium with asymmetric information exists are not in general known. There do not appear to be any tractability problems of a comparable magnitude preventing experimental study of convergence, stability or price-maintenance.

A few remarks by way of summation and conclusion:

1. We have contrasted and compared the economic and psychological approaches to risk-bearing. We hope this has placed a clearer perspective on the extent of disagreement. Primarily, economists and psychologists come to these topics attempting to answer different types of questions. Much of the divergence in theories is natural given these sets of questions.

Economists are primarily concerned with behavior which individuals would continue to exhibit (or come to exhibit) if comparable circumstances were repeatedly incurred. This presumably grows out of the pervasive attention paid in economics to equilibrium concepts and phenomena. Economists recognize that behavior of individuals and of their socioeconomic

systems will fluctuate following changes in underlying parameters, and attempt to describe the effect of perturbations in terms of the situation which will result when these fluctuations have died down.

This is a perspective we have not seen in the psychological literature. Why not is a question requiring more knowledge of the history of psychological thought and of the nature of the evolutionary process in intellectual disciplines than we possess. It seems palatable, however, to draw the following conclusion: that the risk-bearing choices of individuals may bear closer relation to the psychological theories when this decision making is novel or unfamiliar to them, but they may come to behave as predicted by the economic theory of risk aversion with experience, feedback, and/or information. It is also more likely that the decisions important to the aggregate pattern of risk-bearing in the economy are made by experienced, rational agents.

2. We have pointed out problems and inconsistencies in the two approaches when discovered. The predominant inconsistencies appear to be in psychological theories, although both have some difficulty in explaining all relevant phenomena.

A feature of the psychological literature which economists would regard as a major shortcoming is the lack of interpersonal comparison implications. Households and firms persist in exhibiting diversity in risk-bearing, which economists attempt to explain and interpret. That the psychological literature is exclusively introspective, and offers no predictive explanations of diversity across individuals, serves to reduce, we think, the extent of serious attention economists pay to this literature.

3. We have compared psychological and economic experimental techniques. We have pointed out the methodological problems present in experiments, and the way different experimental designs can circumvent many of these problems.

4. We have reported the results of a set of experiments designed to answer the question, "are risk preferences consistent, so that behavior of individuals in one risk choice context can yield predictors of their risk-bearing decisions in other contexts?" Tentative support for the risk-consistency hypothesis was found. While the experiments were not designed to discriminate between psychological and economic theories, the results are as expected utility maximization would predict.

5. We have suggested improvements to this set of experiments, and directions for future economic research in this area.

Footnotes

[1] See, for example, Grether and Plott [1979].

[2] We do not expect complete agreement from all economists on the way that we have characterized the economic approach, or uniform enthusiasm regarding the value and validity of experimental evidence. The economic literature cited has a commonality of motivation and paradigm, however, which is strong in comparison with either the psychological literature cited, or the economic literature in such areas as macroeconomic policy. Thus, we find justification for treating "the" economic approach as unified.

[3] Arrow [1965] and Pratt [1964], outlined below, are examples of concern with this question.

[4] See also Friedman and Savage [1948].

[5] Arrow [1971] and an extensive literature deal with this important topic.

[6] For example, Rothschild and Stiglitz [1970], discussed below.

[7] Clearly, a more risk averse person would pay less for insurance (or pay more to avoid insurance) if $\tilde{\varepsilon}$ were negatively correlated with w.

[8] Note that the case where $R(u_a,w) = A > B = R(u_b,w)$, all w, is a counterexample to Ross' theorem, but is covered by the theorem of Kihlstrom et al. Thus, in this case, $\pi_a \geq \pi_b$ if $\tilde{\varepsilon}$ is independent of $\tilde{w}$, but $\pi_a < \pi_b$ for some uncorrelated, nonindependent $\tilde{\varepsilon}$.

[9] The assumption that the set of lotteries is countable is never used by Coombs. Modelling alternatives as countable is pervasive in the psychological literature, and may stem from Pollatsek and Tversky [1970], the most theoretical or mathematical paper we found regularly cited. Pollatsek and Tversky employ an extensive system of measurement reduction to an order on the alternative set. As this is a mathematical tool unfamiliar to us, it is not clear whether countability plays a critical role.

[10] Their words. Clearly, zero probability events and impossible events are not the same. The uniform distribution on the unit interval ascribes zero probability to every possible outcome. Kahneman and Tversky (like all the psychological literature we have seen) restrict their attention to choice over discrete probability measures, for reasons not apparent.

[11] Kahneman and Tversky [1979], p. 277.

[12] The psychological theories discussed might be able to explain gambling in a similar way if they were developed, as expected utility maximization is, from choices over consumption bundles.

[13] Kahneman and Tversky [1979], p. 265.

[14] It is incautious, we think, to conclude that subjects who don't bother to calculate the truth will, in aggregate, display a response pattern which is evenly distributed, that is, random with respect to choice patterns of subjects who do calculate. Nor is randomizing order and location a guarantee of random response patterns from unconcerned subjects. Unmotivated subjects may disproportionately choose the alternative with

the briefer description, or the one expressed using fewer numbers, or may avoid choices with the number 13.

[15]Fiorina and Plott [1975] report on an experiment where groups of 5 subjects were to choose via majority rule a point on a blackboard, from (0,0) to (200,150). Preferences (and disagreements) were induced by giving each subject a bliss or most preferred point, and informing each of the dollar value earned should the group agree on that point, and the rate at which earnings declined over concentric circles moving away from the bliss point. Experiments were run under high payment and low payment conditions. Both conditions paid subjects a reasonable wage. In the high payment condition, earnings averaged \$7.57 at the Majority Rule Equilibrium, A, and subjects stood to lose amounts ranging from \$0.84 to \$1.45 (averaging \$1.19) per unit of distance if a departure from A was not in their preferred direction. Results were clustered tightly at A, which was predicted by several theories, with a (Euclidean distance) standard deviation of 5.2 when full communication was allowed, and 8.3 when communication was limited to motions and votes.

The low payment condition paid on average of \$6.50 at A, gradient amounts ranged from \$0.01 to \$0.05 (not \$0.84 - \$1.45). Now no theory predicted the results, which were scattered about, with standard deviations of 21.9 and 17.3 for full and limited communication.

[16]The direct impetus for our development of this methodology and conduct of these experiments came from conversations with Julian Simon, and discussions among the authors about Maital, Filer and Simon [1978].

[17]We limited suggestions to "if you tell me how many shares you are considering, I can calculate the cost, or if you tell me how much you want to invest in that stock, I can calculate the number of shares," and "have I recorded this correctly: you wish to buy 25 shares of alpha, and sell 20 of delta ..." The frequent question after the first week was answered with "You may change your portfolio or stay with the same stocks, whatever you wish."

[18]We are not aware of such a proof. We suspect it to be true that the portfolio problem is isomorphic to the insurance problem. If this conjecture is true, credit goes to a private conversation with Stephen Ross. If not, it was our conjecture which was false.

[19]Much of the risk shifted to insurance companies is eventually transferred in capital markets, also.

[20]The errors in the independent variables represent a problem, nonetheless. With two independent variables the error problem should be attenuated, and heuristically more appealing than srious dependent variable errors.

[21]This variance is computed on the prior 36 weeks (it is not the variance used to generate prices, as this was unknown to subjects).

[22]The reason for summing over 8 instead of 7 securities is inclusion of the risk-free asset (at zero variance).

[23]$\mathrm{Var}(x_1 x_2) = \bar{x}_1^2 \ \mathrm{Var}(x_2) + \bar{x}_2^2 \ \mathrm{Var}(x_1) + \mathrm{Var}(x_1)\mathrm{Var}(x_2)$, where $\bar{y} = E(y)$, when x_1, x_2 are independent.

[24]Minor technical improvements we would make would be two. One, a substantial increase in the mean profitability of stocks relative to initial commissions, evaluated over only a few 'weeks.' This could either be done directly, or by eliminating or reducing commission charges on 1st week purchases. Two, reduce the chance bets questionnaire to comparisons between a base bet and about 4 alternatives, and multiply scale of bets noticeably. This will mean that the expected gain from bothering to calculate which bet is chosen would be nonnegligible.

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Instructions to Subjects

Thank you for agreeing to take part in an experimental stock-
arket research study. We want to find out how people choose to
uy and sell stocks, using only information about the price movements
f the stocks. This experiment simulates a real buying and selling
ituation, and the prices are as predictable (or as unpredictable)
s on a real stock exchange. Of course, you do not use real money.

First, look at the Stock Price History sheet. It shows recent
nformation on the seven stocks which you can buy or sell. These
tocks were created so that none had stock splits, stock dividends, or
ther unrevealed changes. Cash dividends are included in the price
tself, as if all dividends were immediately reinvested, so that
ou can ignore price changes due to dividends being paid out. The
rices you see are closing prices for the given week.

You manage a portfolio initially worth $10,000. You may buy stocks
ith any part of that sum that you wish, and you can hold any part of
t in cash for as long as you like. But you may not borrow money at
ny time. You will earn interest at 5 per cent per annum on any cash
alance. Credit for interest will be given week by week, though it
ill not be calculated until after you have completed the experiment.
Interest on $10,000 over ten weeks of the experiment would be about
100). To simplify the bookkeeping there will be a flat 1 per cent
harge on each transaction for brokerage and taxes, no matter whether
ou buy or sell one share or a hundred.

You should keep a running record of your financial position on th
Current Financial Position sheet. Do your best to avoid errors in
rithmetic.

After you have had time to place your first orders for your
urchases and sales on the Purchase-Sale form for Week-Two, this
form will be collected.

Then, closing prices for the next Friday will be shown to you,
and you can consider your investment position. Again, indicate your
purchase and sale orders on the Purchase-Sale Order form for Week Two,
and hand the form in.

This process will be repeated for several weekly periods. At the
end of the experiment, you can total up your assets in stocks and cash
and determine how well you did.

You will only be playing against the stock market, of course, and
none of you are affected by what anyone else does. Also, none of your
transactions can be big enough to affect the market price.

At the end of the experiment, you will be paid your earnings in
cash. Your earnings will be equal to $10 plus 1 1/2% of portfolio
profits (or $10 minus 1 1/2% of portfolio losses), adjusted for gains
or losses from the selected chance bet.

CHANCE BETS QUESTIONNAIRE

Below you are shown pairs of chance bets that vary in terms of the chances of winning and losing, and the amounts of money that can be won or lost. For each pair, please choose the bet that you would prefer to play. Indicate your decision by making a check in the space provided under the bet you would prefer to play. Consider each pair separately - do not let your decision in one case influence your decision in another.

One of the pairs of chance bets will be chosen at random. Whichever bet you chose from that pair will be run to provide an amount of gain or loss to be added to or subtracted from your portfolio earnings.

1.	___ 60% to win $2.25 40% to lose $2.75	vs.	___ 80% to win $.05 20% to lose $.10
2.	___ 60% to win $3.50 40% to lose $1.50	vs.	___ 80% to win $.05 20% to lose $.10
3.	___ 60% to win $2.15 40% to lose $2.85	vs.	___ 80% to win $.05 20% to lose $.10
4.	___ 60% to win $1.50 40% to lose $3.50	vs.	___ 80% to win $.05 20% to lose $.10
5.	___ 60% to win $4.50 40% to lose $.50	vs.	___ 80% to win $.05 20% to lose $.10
6.	___ 60% to win $2.75 40% to lose $2.25	vs.	___ 80% to win $.05 20% to lose $.10
7.	___ 60% to win $2.00 40% to lose $3.00	vs.	___ 80% to win $.05 20% to lose $.10
8.	___ 60% to win $2.02 40% to lose $2.98	vs.	___ 80% to win $.05 20% to lose $.10
9.	___ 60% to win $3.00 40% to lose $2.00	vs.	___ 80% to win $.05 20% to lose $.10
10.	___ 60% to win $2.05 40% to lose $2.95	vs.	___ 80% to win $.05 20% to lose $.10
11.	___ 60% to win $4.00 40% to lose $1.00	vs.	___ 80% to win $.05 20% to lose $.10
12.	___ 60% to win $2.50 40% to lose $2.50	vs.	___ 80% to win $.05 20% to lose $.10

Stock Price Histories for Prior 36 Weeks

ALPHA	BETA	GAMMA	DELTA	EPSILON	ZETA	ETA
20 1/2	19 1/2	50	64 3/8	88 1/4	18 1/4	32 5/8
20 1/4	20 1/4	45 7/8	64 1/8	82 7/8	18 1/4	34 7/8
19 1/2	19 3/4	38 3/4	65 3/8	89 7/8	18 1/8	32 1/2
20 1/4	19 1/8	39 3/8	67 3/4	93 3/8	17 7/8	28 3/4
20 1/2	17 3/8	40 1/8	68 1/4	101 3/4	18 3/4	30 3/8
20 1/4	17 5/8	44 1/2	71	105 7/8	18 1/2	33 1/2
20 3/4	17 1/2	41 3/4	72 1/8	101 5/8	18 3/4	35 1/4
20 1/4	19 5/8	39	74 3/8	97 5/8	18 7/8	34 1/4
19 3/4	18 7/8	36 1/2	70 5/8	93 3/8	19 1/4	36 1/4
19 7/8	21 5/8	33 1/2	69 1/2	82 5/8	19 1/2	34
20 1/8	21 1/8	30 5/8	66 1/2	83 3/4	19 1/2	31 3/8
19 5/8	24 1/8	32	67 7/8	85 1/8	19 1/2	27 3/4
19 5/8	23	29 1/8	68 1/8	85 1/8	19 1/8	26 1/8
18 5/8	23 3/8	28 1/4	68 3/8	87 5/8	19 1/8	24 7/8
18 1/4	23 1/8	27	70 3/8	79 1/4	20	23 1/2
18 3/8	24 7/8	27 7/8	70 3/8	71 3/8	19 5/8	26 3/8
19 1/8	25 3/4	26 3/4	71	76 1/8	18 3/4	26 3/4
18 3/8	22 5/8	31 3/4	73	65 3/8	19 1/4	28
17 3/4	25 1/4	33 3/4	79	65 1/4	19 1/8	27 3/4
17 3/4	23 3/4	35 1/8	84 5/8	64 1/4	19	28 1/2
17 7/8	22 1/8	43 1/8	85 3/4	61 5/8	18 3/8	28 3/4
17 5/8	21 3/8	39 1/8	87 3/8	61 5/8	18 1/4	30 3/4
16 7/8	20 5/8	32 1/8	89 7/8	62 1/2	18 3/8	32 1/8
17 1/2	20 3/8	31 5/8	90 1/8	60	18 1/2	33 3/4
17 3/4	21 3/4	29 1/2	91 1/2	60 3/4	18 3/4	35 5/8
19 5/8	22 1/4	29 3/8	95 1/2	66 1/8	18 7/8	35 3/8
19 7/8	22 1/2	29 1/8	97 1/2	62 1/8	18 7/8	33
20 1/8	22 /12	33 1/2	95 7/8	61 3/8	17 3/4	32 1/2
20 1/4	22 3/4	32 1/8	96 1/4	66 1/8	17 7/8	32 5/8
20 3/8	24 1/2	33 3/8	100 5/8	72 1/2	17 1/4	29 7/8
20 1/4	24 1/2	31	104 1/8	73 1/2	17 3/4	28 1/2
19 1/2	24	32 5/8	106 7/8	81 5/8	17 5/8	26 5/8
20	25	37 5/8	103 3/4	78	17 1/4	26 5/8
20 1/8	26	37 1/8	107 1/8	75 3/4	17 1/8	22 7/8
21 5/8	26 3/4	36 7/8	108 1/2	71 1/4	17 3/4	22 3/4
21 1/4	25 1/2	38 3/4	105	71 5/8	18	20 3/4